AEROLOGICAL SOUNDINGS OF THE SURFACE BOUNDARY LAYER AT MIZUHO STATION, EAST ANTARCTICA

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Abstract: Aerological soundings were carried out at Mizuho Station, East Antarctica as part of POLEX-South.

Surface inversions were found on all soundings from the middle of March through the middle of October. The surface inversion thickness was not larger than 500 m. The thickness under clear skies was larger than that under cloudy skies. Its intensity became stronger steadily from 3°C in February to about 20°C in May, and then weakend gradually from July to October under clear skies, intensity under cloudy skies was weaker than under clear skies, the difference being large in winter. The temperature difference of inversion top between strong and weak cases was small: the intensities of surface inversions were determined almost entirely by the surface temperatures. Wind speeds aloft increased with height from the surface to 150 m, thereafter decreased to 900 m height and then increased again. The wind direction turned counterclockwise with height so as to blow parallel to the contour line of the terrain in the lowest few hundred meters in about 60% of all cases.

Not only the radiative heat loss but also the air advection from the interior is important in forming the surface inversion at Mizuho Station.

The surface inversions here are destroyed not merely strong wind, but by the passage of synoptic scale disturbances.

1. Introduction

Aerological observations in Antarctica have been carried out at more than 10 coastal stations and a few inland stations since the beginning of the International Geophysical Year in 1957. Detailed studies related to the surface boundary layer using the aerological data have been made by many investigators.

The behavior of the katabatic wind near the coast was studied by BALL (1960), and that inland by MATHER and MILLER (1967). However, the strong stationary

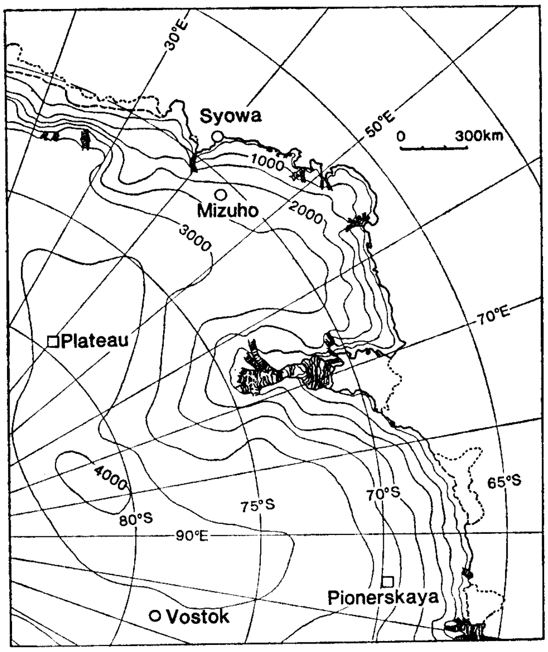

Fig. 1. Stations in East Antarctica referred to the paper.

katabatic wind and the thermal structure in the area classified as Cold Katabatic by DALRYMPLE (1966) has not been clarified so much.

The aerological observations were carried out at Mizuho Station (70°41′53″S, 44°19′54″E, 2230 m a.s.l.) which belongs to the Cold Katabatic zone during the wintering of the 21st Japanese Antarctic Research Expedition (January 1980–January 1981) (Fig. 1). The object of these observations was to clarify the thermal structure and the wind regime of the surface boundary layer, so low altitude radiosondes were used.

2. Instruments

Ground equipment used for these observations was a RD-65A receiving system composed of a parabola antenna of 1 m diameter, a driving unit, a pedestal and a recording unit. The antenna and the driving unit were set up above the pedestal fitted on a pipe frame constructed on the snow surface, about 200 m from the base site, and all equipment except the frame was covered by a reinforced-plastic dome in order to protect it from strong winds, drifting snow and cold. The recording unit was set in the POLEX hut which was kept warm constantly.

JWA-75TWS type low altitude radiosondes were modified to be suitable for this experiment at Mizuho Station, where the mean surface pressure was about 730 mb and the mean surface temperature in winter was about −40°C. An aneroid barometer capable of measuring at 15 points from about 850 mb to about 550 mb was used for the pressure sensor, and a carboloy wire thermometer was used for temperature measuring. Its accuracy was about ±0.2°C. The frequency of the transmitter used was 1680 Mc.

Latex balloons 300 g in weight were used for launching. The buoyancy of each balloon inflated with helium gas was about 700 g and the payload weighted

300 g, giving an ascension rate of 300 m/min.

3. Results of Observations

The observations were carried out 79 times in the period February 2, 1980 to January 16, 1981. We obtained the surface (2230 m) to 5000 m above sea level.

Examples of temperature and wind profiles are shown in late summer, cloudy and clear sky in early winter, and middle winter in Figs. 2a, 2b, 2c and 2d, respectively. The most striking features of the temperature profiles are the very marked inversions in the surface boundary layer.

From Fig. 2a it is found that the inversions were destroyed near the surface due to solar radiation and that the intensities of inversions were weakened and

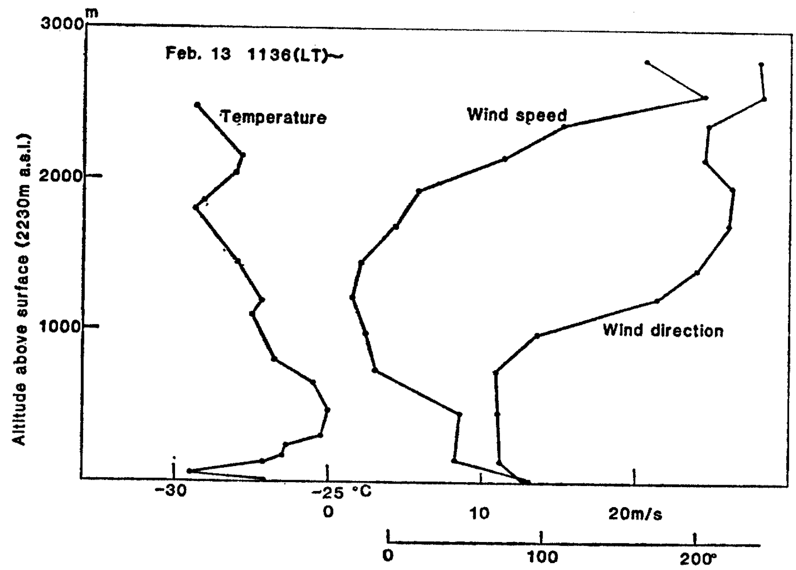

Fig. 2a. Example of temperature profile and wind aloft in late summer.

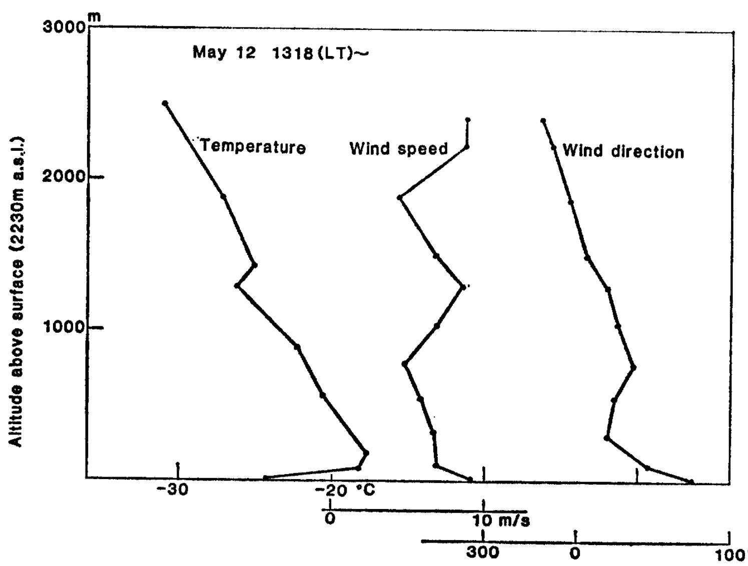

Fig. 2b. Example of temperature profile and wind aloft in cloudy sky in early winter.

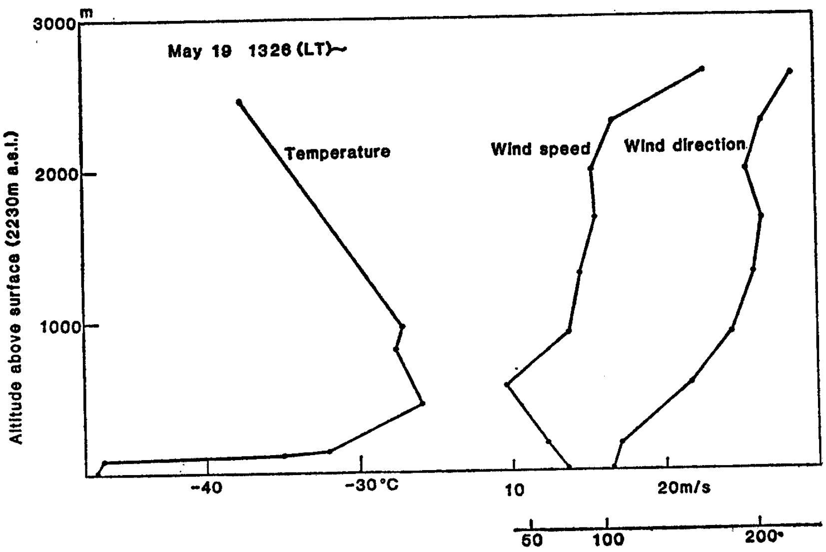

Fig. 2c. Example of temperature profile and wind aloft in clear sky early winter.

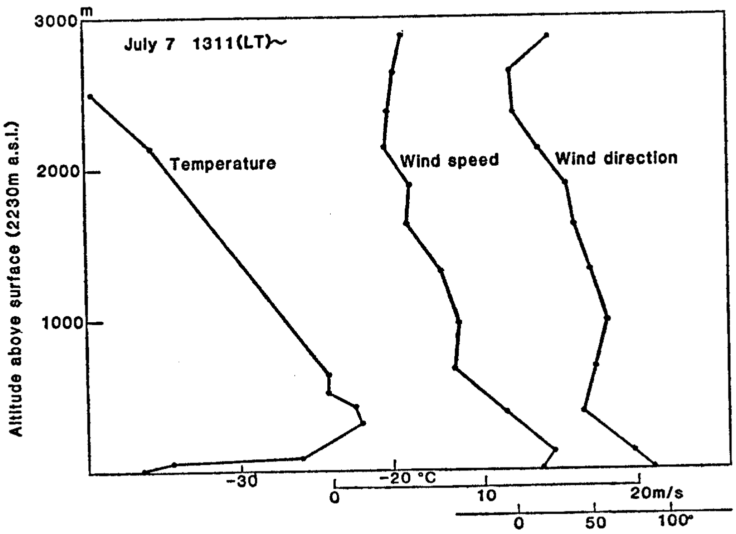

Fig. 2d. Example of temperature profile and wind aloft in winter.

the thicknesses were the surface and weakened and the thicknesses were attenuated by clouds. The wind had a maximum speed near the surface and weakened with increase of altitude even within the inversion layer.

3.1. Surface inversions

The surface inversion is the most characteristic weather phenomenon in the interior of Antarctica. The intensity and the thickness of the inversion obtained by observation from February 1980 through January 1981 are shown in Fig. 3. The thickness is shown in meters in the lower part of the figure, and the intensity is shown in °C in the upper part. Also, the weather at the observation time is shown at the top. Solid circles show the surface inversion. Open circles connected with a fine line and open circles show the position of the upper inversion and its

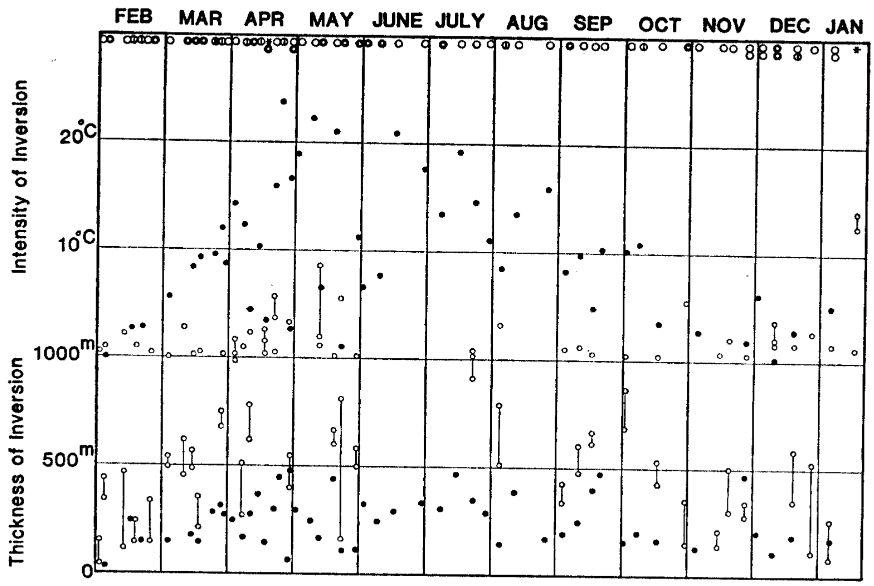

Fig. 3. The annual variation of the thickness and the intensity of the inversion.

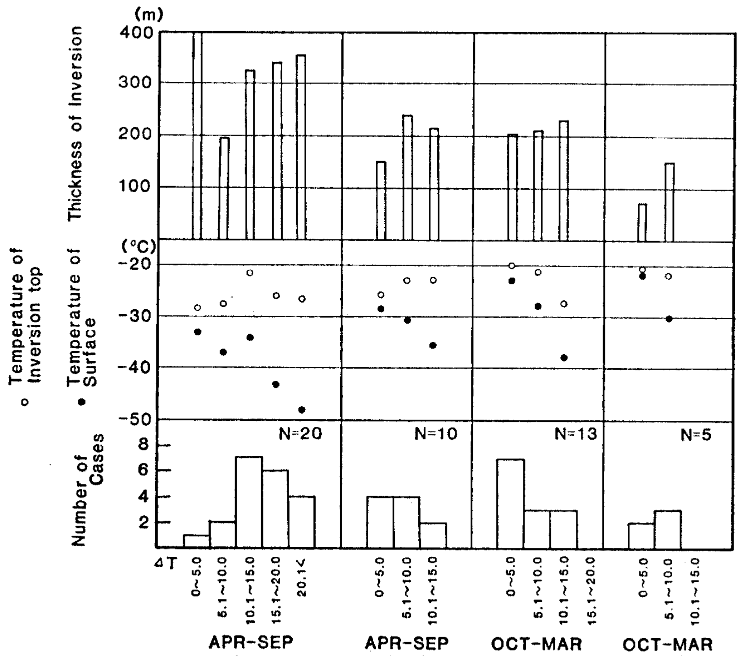

Fig. 4. Frequencies of surface inversion thickness and intensity, temperature of top and bottom.

intensity, respectively.

(1) Permanent surface inversions were found in all soundings from the middle of March through the middle of October.

(2) The thicknesses of the inversions was not larger than 500 m, and inversions under clear skies were larger than those under cloudy skies.

(3) The intensity of the surface inversion became stronger steadily, from about 3°C in February to about 20°C in May, and then weakened gradually from July to October.

(4) The intensities under cloudy skies were weaker than under clear skies, the discrepancy was large in winter.

(5) The intensities of the upper inversions were below 6°C. Figure 4 shows the statistics of the surface inversion. This makes these relations clear. The numbers of cases per 5°C, the mean temperatures of the surface and of the top, and the mean thickness are shown.

(6) The intensities of the surface inversions in winter were between 10.1 and 25°C in 80% of the case. The thicknesses were about 300 m under clear skies, and other hand, 80% of the case had intensities below 10°C, and their thicknesses were about 200 m under cloudy skies.

(7) Inversions in transitional seasons and in summer were weak and thin.

(8) The temperature difference of inversion top between strong case and weak case was not so large. The intensity of surface inversions was determined almost entirely by the surface temperatures.

3.2. Winds aloft

Wind is the most important climatic element at Mizuho Station, which is in the Cold Katabatic zone. The constancy of surface wind speeds and directions is very high, especially in winter (SASAKI, 1974).

The wind speed frequencies per 5 m/s of wind speed at various altitudes in winter and other seasons are shown in Fig. 5, and also the wind direction fre-

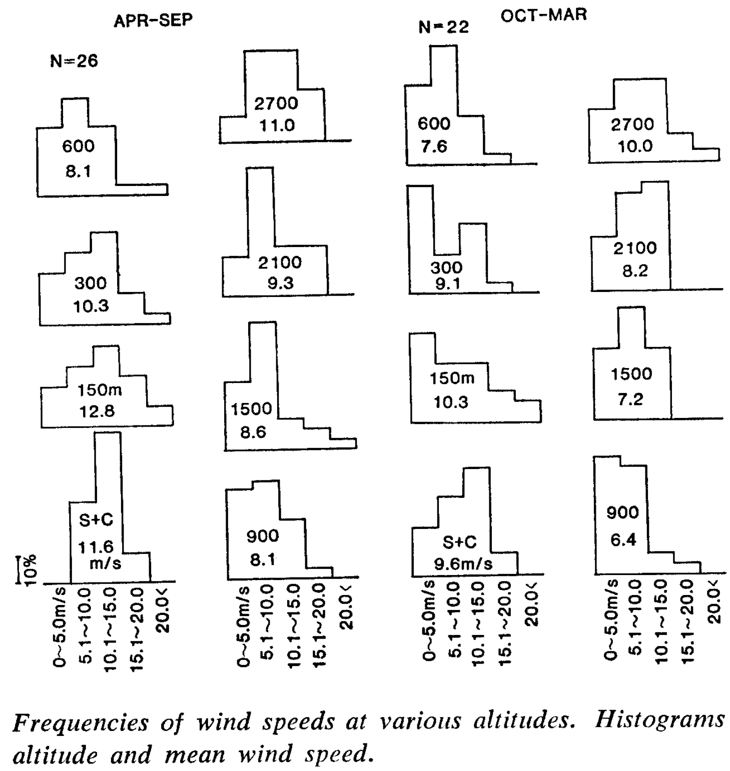

Fig. 5. Frequencies of wind speeds at various altitudes. Histograms show altitude and mean wind speed.

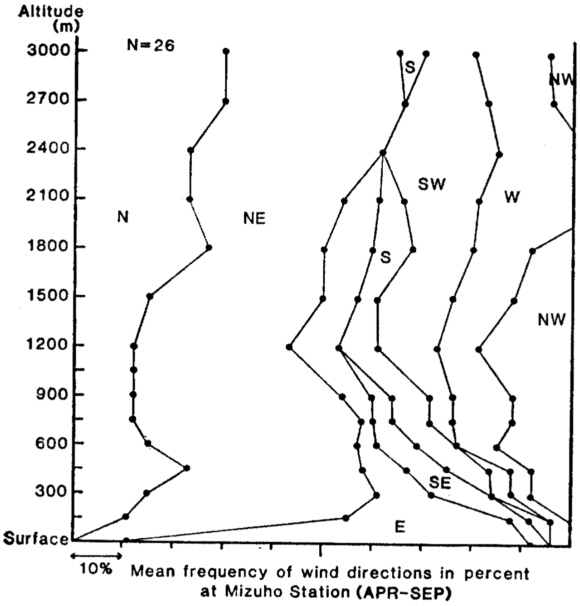

Fig. 6a. Frequency of wind directions at various altitudes in winter.

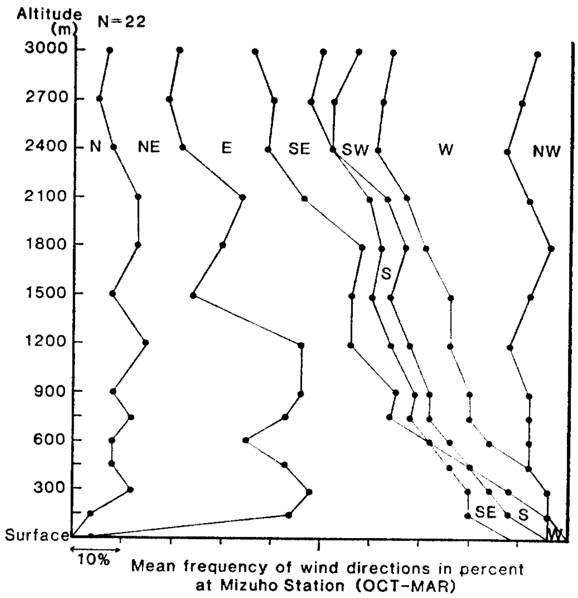

Fig. 6b. Frequency of wind directions at various altitudes in other seasons.

quencies are shown in Figs. 6a and 6b.

(1) Surface wind speeds were very consistent. As seen from the great concentration around the mode, mean wind speed was 11.6 m/s in winter and 9.6 m/s in other seasons. The prevailing wind direction was between 80 and 100 degrees in about 80% of the cases. This wind regime is very similar to that of Pionerskaya (69°44′S, 95°31′E, 2741 m a.s.l.) (DALRYMPLE, 1966).

(2) Wind speeds aloft increased with height from the surface to 150 m height. Thereafter it decreased to about 900 m height and increased again to the tops of the soundings. The steadiness of the wind became smaller with height.

It has been found that the wind speed at the top of the inversion was considerably higher than that observed at the surface at the South Pole (90°, 2880 m a.s.l.) and Vostok (78°21′S, 106°48′E, 3488 m a.s.l.) (DALRYMPLE, 1966). But the relation at Mizuho Station was reversed, due to strong surface winds.

(3) Wind speeds at each level were higher in winter than in other seasons.

(4) The wind directions at the surface turned counterclockwise with height so as to blow parallel to the contour line of the terrain in the lowest few hundred meters in about 60% of all cases. The wind direction in summer became less regular with increase in height.

4. Discussion

As stated above, the intensities and thicknesses of the surface inversions under clear skies in winter at Mizuho Station were almost always between 10 and 20 degrees, and about 300 m, respectively. These are weaker and lower compared to those at the South Pole Station located in the Cold Interior zone where the intensity and the thickness in winter are about 21°C and 650 m, respectively, and at Vostok

Station located in the Cold Core zone where the intensity and the height in winter are about 24°C and 900 m, respectively. There is no doubt that the strong surface inversion was brought about through the intense radiative heat loss from the surface.

The net radiative heat loss from the surface at the time of the strong inversion is about 0.03 ly·min^{-1} at the South Pole (SCHWERDTFEGER, 1970) and about 0.02 ly·min^{-1} at Vostok Station (DALRYMPLE, 1966), and about 0.07 ly·min^{-1} at Mizuho Station (YAMANOUCHI *et al.*, 1981).

Although this net heat loss is balanced by the vertical eddy flux of heat, heat of sublimation, and heat conduction from the ground, the most important element at Mizuho Station is possibly the vertical eddy flux of heat. In equilibrium, the eddy flux of heat caused by the strong surface wind at Mizuho Station is much larger than that at the South Pole. If the wind at Mizuho Station were weak in the inversion, the surface temperature would be lowered more than about 10 degrees corresponding to that at the South Pole due to the net radiative heat loss. But, the incline of 4×10^{-3} of the terrain and inversion strength of 15 degrees bring about an "inversion wind" of 17 m/s, about 4 times that at the South Pole on the terrain having an incline of 1×10^{-3}, under the same thermal condition (SCHWERDTFEGER and MAHRT, 1970). That is, the large incline of the terrain tends to prevent development of an inversion. This raises another question, namely, why the height of the inversion at Mizuho Station is lower than that at the South Pole. The large vertical eddy flux of heat and the lower top of inversion may contradict each other.

We cannot prove what the reason is conclusively, but it may be caused by

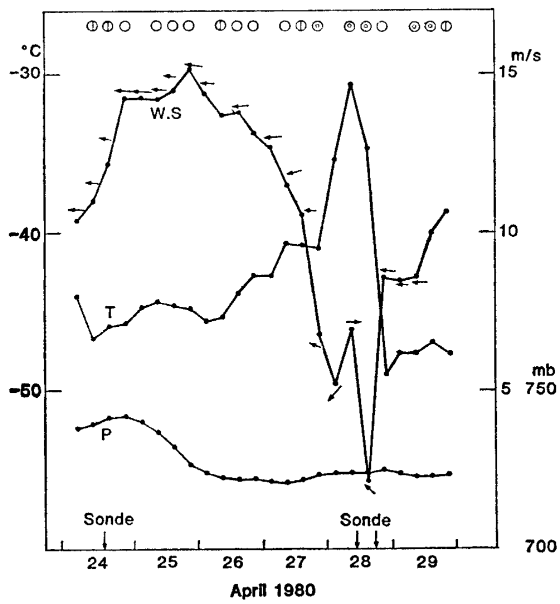

Fig. 7a. Variation of surface meteorological elements (temperature, pressure, wind speed, wind direction and weather) on the occasion of destruction and reformation of a surface inversion.

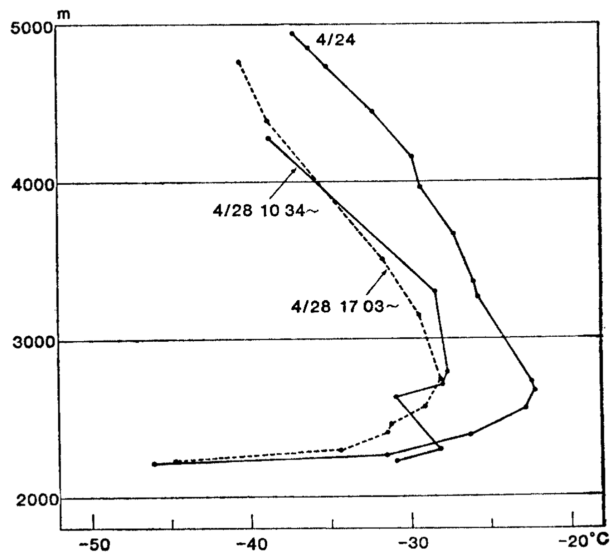

Fig. 7b. Change of temperature profile on the occasion of destruction and reformation of the surface inversion.

the subsidence of air near the top of the inversion, which is expected to be stronger over Mizuho Station.

The term "permanent surface inversion" is used in Subsection 3.1, but it was not demonstrated whether it is really permanent or not, because soundings were done 1 or 2 times per week.

One case of destruction of the surface inversion in winter was observed.

Figure 7a shows the sequence of surface of meteorological elements from April 24 through 29. With the approach of a synoptic scale disturbance, wind speed became strongest on the 25th but temperature did not rise. Abrupt rising of temperature took place with abrupt decrease of wind speed and cloudy sky on the 28th, associated with a frontal passage. After the frontal passage, abrupt temperature falling and increasing of wind speed took place. During this period, radiosonde observations were carried out three times. Figure 7b shows the change of temperature profiles. From previous considerations, it is concluded that the surface inversion was destroyed not merely by the strong wind, but by the frontal passage. Invasions of synoptic scale disturbances were observed a few times even in winter, so it may be that there were several destructions of surface inversions. Figure 7b shows one more interesting phenomenon. The intensity of the surface inversion increased about 15°C in only 7 hours. It may be that advection of air in the lowest layer results in the strengthening of the surface inversion. It is concluded that reformation of surface inversions in the Cold Katabatic zone is affected by advection of air in the surface boundry layer more than in the Cold Interior and the Cold Central Core zones.

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